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Potato Diseases in Montana

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CRINKLE-MOSAIC SYMPTOMS IN THE LEAFLETS OF A BLISS TRIUMPH POTATO

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KEY TO POTATO DISEASES

The common potato diseases have symptoms by which they can be readily recognized. These symptoms are arranged in the form of a key with which the different diseases can be identified with considerable accuracy.

HOW TO USE THE KEY

Read the main headings given under the capital letters A, B, and C, and decide from the symptoms of the specimen to be identified in which group it belongs. In this group read the next main heading given under the Roman numerals I and II, and so on until the name of the disease is given.

Example: Specimen of potato plant to be identified is normal in appearance except that it has prominent yellow blotches in leaves. Blotches are ¼ inch wide or larger.

Question	Answer
A. Tuber disease	No
B. Leaf disease	Yes
I. Leaves partly or entirely dead	No
II. Leaves not dead	Yes
1. Leaves mottled	No
2. Leaves not mottled	Yes
a. Vines dwarfed	No
b. Vines not dwarfed	Yes
aa. Vines normal except new top leaves sometimes mottled. Other leaves have brown streaks and small dead spots	No
bb. Prominent yellow blotches in leaves, often larger than ¼ inch wide—Calico	Yes

Now turn to the description of the specific disease, in this case Calico, and compare it with the specimen to be identified.

It is desirable to have one or more good typical specimens of potatoes or vines for classifying a disease. Single potatoes or vines often have more than one disease. In a field compare suspected plants with many surrounding plants that look normal.

KEY TO POTATO DISEASES IN MONTANA

A. TUBER DISEASES

I. Symptoms visible on surface of tubers.

1. Shape of tuber normal.

a. Flesh of tuber normal.

aa. Black specks or spots (1/32 to ½ inch wide) on skin; dirt that won't wash off.....Rhizoctonia. Figs. 3, 4.

bb. Scabby spots in skin, roughly circular, ⅛ to ½ inch wide.....Scab. Fig. 5.

cc. Surface and adjacent flesh green or reddish purple .....Sunburn.

dd. Surface with raised little white to brown spots.....Enlarged lenticels.

ee. Surface pimply; small, circular brown spots with white centers ⅛ inch below surface.....Nematodes.

ff. Sprouts abnormally thin and slender, often numerous.....Spindling sprout.

b. Flesh of tuber abnormal; rotten or moldy.

aa. Rots; surface sunken; white or brown molds of tubers in storage .....Dry rot. Figs. 10, 11.

bb. Bud end or other parts soft; drops of juice leaking out.....Frost.

2. Shape or size of tuber abnormal.

a. Tubers too long, thin and spindle-shaped; many eyes; (vines narrow, dwarfed and upright) .....Spindle tuber. Figs. 15, 16, 17.

b. Tubers very large, irregular, and often cracked; (vines too large and coarse) .....Giant hill. Fig. 18.

c. Ten to 200 very small tubers per hill .....Witches' broom. Fig. 20.

II. Symptoms not visible on surface of tuber; flesh rotted or discolored.

1. Brown to black streaks or specks in flesh near stem end.....Stem end browning (Fusarium).
2. Soft, slimy rot (in field).....Blackleg. Fig. 6.
3. Brown to black specks or lines scattered through flesh, frost or heat injury in field or storage .....Net necrosis.
4. Irregular black region or cavity in center; improper storage .....Black heart.
5. Centers hollow, brown to white, sometimes moldy .....Hollow heart.

B. LEAF DISEASES

I. Leaves partly or entirely dead.

1. Spots brown to black, roughly circular, 1/16 to ½ inch wide; larger spots with concentric lines .....Early blight. Fig. 7.
2. Lower sides of veins brown to black; petioles with brown to black streaks; leaflets partly or entirely dead; often with small, brown spots.....Rugose mosaic. Fig. 13.
3. Leaflets with ends and edges brown to black; often upward rolled; due to leaf hoppers and hot weather.....Tip burn.

II. Leaves not dead, vines usually dwarfed.

1. Leaves mottled (scattered yellow or light green spots).
   a. Leaves normal except dimly mottled, vines not dwarfed.....Super-mild mosaic, Pl. II.
   b. Mottling prominent, plants slightly dwarfed, leaves abnormally wrinkled .....Mild mosaic.
   c. Mottling prominent, plants dwarfed and narrow, leaflets badly wrinkled and light colored; tubers too small..... .....Rugose or crinkle mosaic. Cover page.

d. Leaves much dwarfed, crinkled, and mottled; borne on dwarfed, spindly stems ..... Mosaic and witches' broom.

e. Like c, but leaves often curled and rolled; borne on narrow, upright vines ..... Mottled curly dwarf.

f. Lower leaves rolled upward, brittle, and light colored; top leaves mottled ..... Mosaic and leaf roll.

2. Leaves not mottled.

a. Vines dwarfed.

aa. Lower or most leaves rolled upward, very brittle, light colored; margins slightly wavy ..... Leaf roll. Fig. 19.

bb. Leaves extremely dwarfed, often with yellow margins; borne on dwarfed, spindly stems ..... Witches' broom. Fig. 21.

cc. Leaves abnormally small and pointed; borne on upright, narrow vines ..... Spindle tuber. Fig. 14.

dd. Leaves smaller than in cc, not pointed; often curled downward; tubers cracked ..... Unmottled curly dwarf.

b. Vines not dwarfed, or if dwarfed, only slightly.

aa. Vines normal except new top leaves sometimes mottled; other leaves have brown streaks and small dead spots ..... Rugose mosaic (primary). Fig. 13, Pl. I.

bb. Prominent yellow blotches in leaves, often larger than ¼ inch wide ..... Calico.

cc. Vines normal, except top leaves are yellow or have yellow margins; too many stems in tops; new tubers sprouted.....Witches' broom (primary).

dd. Vines normal, but top leaves yellow and upward rolled; sometimes brittle.....Leaf roll (primary).

ee. Top leaves purple to yellow, rolled upward, but not brittle; usually aerial tubers, or tubers clustered at base of stem.....Rhizoctonia. Fig. 4.

ff. Leaves and stems yellow and wilting; black streaks in stems.....Blackleg or Verticillium wilt. Fig. 6.

gg. Yellowing less prominent than in ff; stem brown inside base.....Fusarium wilt.

C. STEM DISEASES

I. Aerial tubers absent.

1. Brown to black streaks on stems and leaf petioles.....Rugose mosaic or blackleg.
2. Surface of stem normal; top leaves yellow to light green, rolled upward, and wilted.....Wilt (Fusarium).
3. Brown spots and often a white mold on stem near or below surface of soil; top leaves rolled and yellow to purple.....Rhizoctonia.
4. Stem easily pulled; at least underground part black; leaves usually yellow and wilted.....Blackleg.
5. Plant appearing abnormally late.
   a. Sprouts with a black rot.....Blackleg.
   b. Sprouts with brown spots.....Rhizoctonia.
   c. Young vines narrow; leaves too small.....Spindle tuber. Fig. 14.

d. Young vines prostrate; leaves yellow, brittle, and usually rolled.....Leaf roll. Fig. 19.

6. Vines abnormally large and coarse; tubers large, irregular, and often cracked.....Giant hill.

II. Aerial tubers present.

1. Stems abnormally numerous, slender, spindly, dwarfed, and chlorotic; aerial tubers small; top leaves not rolled, except in combination with leaf roll.....Witches' broom.

2. Stems nearly normal; top leaves usually rolled upwards; aerial tubers usually ½-1 inch in diameter, and usually not numerous .....Rhizoctonia. Fig. 4.

3. Stems thick; symptoms like leaf roll and witches' broom together; tops bright colored; aerial tubers on swollen nodes.....Psyllid yellows.

Potato Diseases in Montana

INTRODUCTION

The object of this bulletin is to illustrate and describe various potato diseases so that they may be identified, and to recommend effective methods of preventing losses from these diseases.

For several years about 35,000 acres of land in Montana have been planted annually in potatoes, with an average yield of 109 bushels per acre. Average yields have fluctuated greatly from year to year, as well as the yields of individual growers. This variation may be attributed to disease, unfavorable weather, unsuitable soil, and poor cultural practices. The direct loss caused by potato diseases in Montana is about 16 per cent, a large part of which could be prevented by the adoption of the approved methods of control. The control of most, if not all, of these diseases depends upon prevention instead of cure.

CAUSES OF DISEASES

The destructive diseases of potatoes which occur in Montana are caused by parasitic fungi, bacteria, or viruses.

A fungus is a plant belonging to the lower forms of life. In nature fungi or molds are white or of various shades of red, orange, black, and the like. The part of the fungus which corresponds in purpose to the roots and stems of ordinary plants is called the mycelium (Fig. 1). Single strands of the mycelium often are not visible to the naked eye, but in quantity they are visible as molds. If a fungus lives entirely upon dead organic matter it is called a saprophyte; if upon living tissues, it is called a parasite. There are all gradations between parasites and saprophytes, for a fungus may be parasitic for a while and then live for months as a saprophyte, or the reverse condition may exist. Nearly all fungi reproduce by spores (Fig. 2), which are very small. These spores correspond to the seeds of crop plants, and require favorable conditions of moisture and temperature for their germination and growth.

Bacteria are very much smaller than fungi and are not thread-like, but spherical or more or less elongated. They are the lowest form of plant life, and are so small that single ones

can not be seen with a naked eye or a simple hand lens. In reproduction each bacterium divides into two parts. The process of growth and division continues rapidly so that they soon form countless numbers. Many bacteria are harmless, but some cause diseases in plants, and others cause diseases in animals.

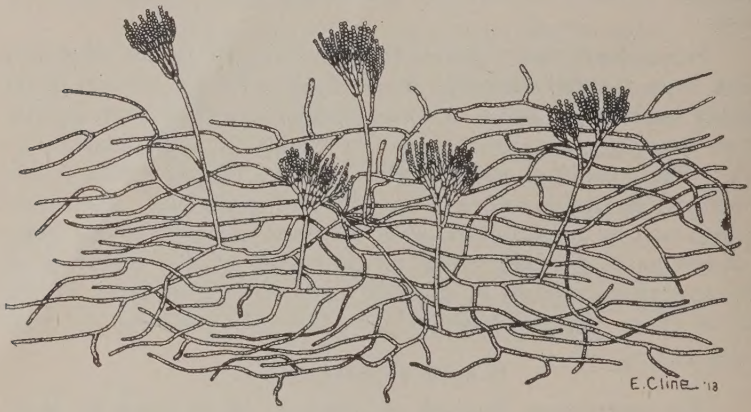

Fig. 1. A common fungus (mold) called blue mold (Penicillium), showing the fungous threads (mycelium) and the 1-celled spores (reproductive bodies). Magnified 150 times.

Viruses are unlike fungi and bacteria. The causes of virus diseases have not yet been seen. However, there is some contagious substance in the juice of virus-diseased plants that causes the disease, and spreads it from diseased to healthy plants. Viruses cause mosaic, yellows, and other diseases of plants, and many diseases of animals.

METHODS TO CONTROL DISEASES

There are five important factors to be considered in a program for controlling diseases of potatoes; namely, seed selection, crop rotation, seed disinfection, spraying, and proper storage. More than one factor is usually associated with controlling a single disease, so these factors must be considered independently, and in their relation to each other.

Fig. 2. Comparison in size between: a, fine sand; b, very fine dust; c, spores of the fungus causing rose rust (Phragmidium); d, spores of the wheat-rust fungus (Puccinia); e, spores of the fungus causing apple scab (Venturia); f, spores of oat smut (Ustilago); g, spores of blue mold of fruit (Penicillium); h, spores of potato dry rot fungus (Fusarium). Magnified 110 times.

SEED SELECTION

Seed selection is probably the most important single factor in disease control. Indirectly it is valuable in securing increased yields and uniformity in size and shape of tubers. Selection of individual hills is the most reliable and satisfactory method, and the best way to accomplish this is by using a seed plot (p. 46).

The Montana Potato Improvement Association, cooperating with the Montana Extension Service, is now providing official inspection and certification of fields grown for seed. The requirements for certification insure high quality in the product,

and most of the certified seed has been so satisfactory that the market demand is increasing yearly. The requirements for certification are practical, so that any careful grower can meet them and produce profitable yields of certified seed.

The potatoes from fields which fulfill the requirements for certification may be sold as certified seed under official tags, "Montana Certified Seed Potatoes," issued by the Montana Potato Improvement Association. They usually command a premium on the seed market in competition with common stock.

The cost of this inspection service is $8 when the application is submitted, an inspection fee of $2 an acre, and a tag fee of 5 cents per sack of 100 pounds. The application fee of $8 includes a membership in the Northwest Potato Association and the Potato Association of America.

CROP ROTATION

Rotation of crops is an important factor in controlling potato diseases, because the causal fungi of many diseases overwinter in the refuse and decaying organic matter in the soil. Some of these fungi remain alive in the soil in the absence of potatoes for at least 3 years, so a 5-year rotation has proved most satisfactory under most conditions. Practice has demonstrated the advisability of adopting a good system of crop rotation suitable to a locality, and following it as a definite plan.

The advantages of using high-quality seed that has been treated, in combination with crop rotation, can not be overemphasized.

SEED TREATMENT

Usually it is profitable to disinfect all tubers used for seed. Many disease-causing organisms are present on the surface of the tubers, and are difficult to recognize when they are not abundant. Seed treatment will kill these surface-borne organisms and should always be practiced in a rotation system of cropping to lessen the chance of soil contamination. When potatoes are planted in infected soil, the value of seed treatment is decreased because the soil is then the main source of infection. Tubers should always be graded before treatment in order to eliminate cracked, bruised, and decaying tubers. To avoid injury, they should be treated while dormant and before

cutting. Either formaldehyde or corrosive sublimate may be used in disinfecting solutions.

1. HOT FORMALDEHYDE SOLUTION FOR POTATO SEED TREATMENT

This is perhaps the most popular and efficient treatment for seed potatoes. It is effective against the causal organisms of disease which are surface-borne such as those causing scab, rhizoctonia, blackleg, and a few others.

For the hot formaldehyde treatment make sufficient solution in the proportion of 1 pint of 40 per cent formaldehyde in each 15 gallons of water, heat the solution to a temperature of 124° to 126° F., and immerse the tubers (preferably in wire baskets or wooden crates) for 3 minutes in this hot solution. After treating, cover the tubers with canvas or sacks for 1 to 6 hours. The correct temperature should be maintained, as too high a temperature is injurious and too low a temperature is not effective.

The advantages of this treatment are efficiency in killing disease organisms, no injury to seed, general availability, low cost, and adaptability for use on a large scale in tanks or in treating machines.

The formaldehyde solution does not lose strength with successive treatments. Its volume needs to be maintained from time to time by adding more solution of the proper strength, i. e., one pint of 40 per cent formaldehyde in 15 gallons of water. Formaldehyde gas is not considered poisonous but it is irritating.

2. COLD FORMALDEHYDE SOLUTION FOR POTATO SEED TREATMENT

Soak the tubers for 1½ to 2 hours in a solution made by adding 1 pint of 40 per cent formaldehyde to 30 gallons of water. After soaking, remove and cover the potatoes for at least 1 hour. If the tubers are treated in sacks, no additional covering is necessary. This treatment is recommended for scab, but is not so effective against rhizoctonia as the corrosive sublimate or hot formaldehyde solution. Wooden or metal containers may be used.

3. COLD CORROSIVE SUBLIMATE (MERCURIC CHLORIDE) SOLUTION FOR POTATO SEED TREATMENT

Corrosive sublimate treatment controls rhizoctonia and scab.

Soak the tubers to be treated for 1½ to 2 hours in a solution made by dissolving 3 ounces of corrosive sublimate in 22½ gallons of water.

Caution. Corrosive sublimate even in very dilute solution is a deadly poison if taken internally, but it is not injurious to the surface of the skin when applied externally. Do not use treated tubers for feeding because they are poisonous. As the name indicates, this solution corrodes metal, so only wooden or crockery containers should be used.

Method of procedure in treating potatoes

a. Have the druggist put up the powdered corrosive sublimate in packages of convenient size, such as 1-ounce or 2-ounce.

b. Dissolve 3 ounces of the poison in a few quarts of hot water in the bottom of a 50-gallon barrel, and then add enough cold water to make 22½ gallons. This makes enough solution to fill a 50-gallon barrel when the potatoes are put in.

c. Immerse the seed (about 1½ bushels), either loose or in a wooden crate, for 1½ to 2 hours. Do not treat in sacks because the organic matter of the sacks reacts with the chemical and weakens the solution.

d. Remove the potatoes from the barrel and spread out to dry if necessary to store them, or plant immediately.

e. To prevent reinfection, use new sacks, or old ones which have been disinfected by soaking them for several hours in the discarded solution.

f. The solution is gradually weakened during the process of treating successive lots of tubers. Its strength should be maintained by dissolving and adding ½ ounce of corrosive sublimate after every 4 bushels of potatoes have been treated, and restoring its volume to the original level. Avoid treating very dirty potatoes, because the more dirt there is present the more rapidly the strength of the corrosive sublimate is reduced. Treat not more than 7 lots of potatoes, and then destroy the solution in such a way that it will not be a source of danger to man, animals, or garden crops.

4. ACIDULATED COLD CORROSIVE SUBLIMATE SOLUTION FOR POTATO SEED TREATMENT

This method has been used in one state for three years,

and the results obtained indicate that it has merit and many advantages over the hot solutions or the long-time treatments.

Soak the tubers for 3 minutes in a solution made by dissolving 6 ounces of mercuric chloride in 22¼ gallons of water to which 1¾ pints of commercial hydrochloric acid (31 per cent acid) have been added. The corrosive sublimate dissolves very readily in this solution. This method has the following advantages: it controls scab and rhizoctonia about as well as the standard treatments, the temperature need not be controlled, there is little danger of injury to the tubers, and it is a rapid treatment.

5. HOT CORROSIVE SUBLIMATE SOLUTION FOR POTATO SEED TREATMENT

Dissolve 2 ounces of corrosive sublimate in 15 gallons of water, heat to a temperature of 126° F., and immerse the tubers for 2 minutes. Remove the tubers, place them in new or disinfected sacks, and allow them to dry, or plant them immediately. These directions must be followed to secure good results and to avoid injury to the tubers. This solution should be used in wooden or concrete vats. Do not feed treated tubers, because they are poisonous.

6. ORGANIC MERCURY COMPOUNDS

Manufacturers have recently advocated some organic mercury compounds for treating potatoes. Although favorable results have been obtained in some tests with these compounds, it is necessary to prove their merit under variable conditions before they can be recommended. They seem to have possibilities of giving beneficial results for the control of seed-borne diseases. In using these compounds, the manufacturer's directions should be strictly followed.

SPRAYING

In order to control early blight, which has become destructive in some localities, spraying the foliage with Bordeaux mixture is advisable. Lime sulphur solution is not a satisfactory spray for potatoes. Spraying potatoes with arsenical compounds for controlling certain insects has been practiced for many years, but a discussion of insect control is not within the scope of this paper.

The materials for the preparation of Bordeaux mixture are copper sulphate (bluestone or blue vitriol) 5 pounds, unslaked lime 5 pounds, and water 50 gallons. This is known as the 5-5-50 formula.

Preparation of Bordeaux mixture.—Have three wooden barrels and two wooden pails. Put 25 gallons of water into one barrel. Dissolve 5 pounds of copper sulphate in this barrel by suspending it over the water in a piece of coarse burlap with a portion of the chemical hanging a few inches under water. It will dissolve much more quickly by this method than if thrown loosely in the bottom of the barrel. Start this a few hours before the solution is needed.

Slake 5 pounds of lime in the second barrel or in a pail. In slaking, add water a little at a time, and stir constantly. The lime should not be allowed to become dry, nor should it be submerged. After the slaking is complete, enough water should be added to make a total of 25 gallons. The lime should be strained through a sieve, 20 meshes to an inch, before mixing with the copper sulphate solution.

Pour into the third barrel, first a pailful of copper-sulphate solution, then a pailful of lime mixture, and so on. If two persons are working together they should pour the two liquids together into the third barrel.

The resulting mixture should be blue. A tinge of green indicates that it has not been properly mixed.

If it is impossible to spray immediately because of unfavorable conditions, ¾ ounce (a heaping tablespoonful) of sugar dissolved in a little hot water should be added to each 50 gallons of Bordeaux mixture. This will keep the spray mixture in good condition for several days. If the sugar is not added, Bordeaux mixture deteriorates very rapidly, becoming practically worthless if allowed to stand over night. The best plan is to make it immediately before using.

Spraying potatoes requires from 75 to 125 gallons per acre, depending upon the size of the plants. A pressure of at least 100 pounds should be maintained while spraying.

Chemical hydrated lime is satisfactory for the preparation of Bordeaux mixture, and can be used as a substitute for quicklime. Agricultural limestone (calcium carbonate) and ordinary

plasterer's or finishing lime containing only 55 to 60 per cent of active calcium hydroxide carry too much inert material to be entirely satisfactory for making Bordeaux mixture.

STORAGE

Various rots of potato tubers cause considerable loss each year due to poor ventilation, high humidity, and unfavorable temperature. The best storage facilities for potato tubers are provided when the temperature is kept between 35° and 40° F., and the storage room is kept well ventilated. Under these conditions the losses from tuber-rots and other storage diseases will be reduced to a minimum.

To kill the organisms that cause various diseases occurring in storage, the storage places should be thoroughly cleaned and disinfected each year before harvest time. For disinfecting, spray the place with either of the following solutions: 1 pound of copper sulphate in 10 gallons of water, or 1 pint of formaldehyde in 10 gallons of water. After spraying, the house should be well aired and dried before it is used for storage.

DISEASES CAUSED BY FUNGI AND BACTERIA

RHIZOCTONIA

Rhizoctonia is one of the most common and injurious potato diseases that occurs throughout Montana. It is the "dirt" that is difficult to wash off from tubers.

Cause.—It is caused by a fungus known botanically as *Corticum vagum* var. *solani* Burt. It is often called Rhizoctonia. It is quite widely distributed in soil and lives as a saprophyte on dead organic matter, including potato refuse.

Economic importance of hosts.—About 185 kinds of plants, including weeds, vegetables, ornamental plants, and field crops, have been listed as subject to attacks by this fungus. Some of the common plants in this list are potatoes, garden beets, sugar beets, carrots, asparagus, cabbage, cauliflower, alfalfa, red clover, and sweet clover. No cereal crop has been reported as being affected by this fungus, so the use of cereals in a rotation is recommended.

Symptoms of Rhizoctonia.—The symptoms vary with the climate, soil, development of the host at the time of infection,

Fig. 3. Rhizoctonia on potato tubers, showing the "dirt that won't wash off." These are the overwintering bodies (sclerotia) of the fungus.

and the virulence of the fungus. Several types of this disease will be described.

1. *Black Scurf of Rhizoctonia.*—Diseased tubers may be recognized by the superficial, irregularly shaped, elevated, dark-brown or black patches of fungous threads (sclerotia, Fig. 3). These sclerotia vary in size from very small black dots to one-fourth inch or more in diameter. The black specks are most easily seen when the tubers are wet, and it is usually at this time that they appear black. They are gray or dark brown when covered with soil. These sclerotia are masses of mycelium in a resting or dormant condition which carry the disease over winter. They are also the source of other types of this disease.

2. *Rhizoctonia Pit.*—This type of disease is believed to occur as a result of the penetration of the mycelium into the potato skin during the early stage of sclerotial development, or from a late growth of young mycelium from the old sclerotia. In severe cases these areas may form folds which rub off easily in the form of dust.

3. *Rhizoctonia Rot.*—This type of disease usually appears rather late in the season on elongated tubers grown under moist conditions when the fungus has become unusually virulent. The source of the disease may be stem lesions, sclerotia, or pits. It is not a common form.

4. *Stem Lesions, Little Potato, and Leaf Rolling caused by Rhizoctonia.*—It is not always possible to distinguish as separate forms of disease the stem lesions, rosette, little potato, etc., for these types of injury are often associated. A typical stem lesion results from the penetration of the mycelium and the death of the invaded host cells. Leaf rolling, rosette, and little potato are secondary symptoms, and there is evidence that they represent responses of the plant to a disturbed condition of nutrition (Fig. 4). Similar effects are sometimes caused by

Fig. 4. Aerial tubers on a potato stem injured by Rhizoctonia.

purely "physiological" disturbances, such as breaking of vines, etc.

The fungus also may attack the stem for a few inches above the surface of the ground. A dark network of fungous threads is sometimes seen upon the underground parts. This may advance above ground and develop a white to gray, spore-bearing layer on the base of the green stem.

Young potato sprouts may be attacked by rhizoctonia which produces small, brown, sunken lesions or spots. These spots cause more or less injury, for in severe cases the sprouts are killed. New vines produced thereafter are often weak and late.

If diseased spots occur on the tuber-bearing stolons, or underground stems, the food supply may be cut off from the young tubers and only little potatoes may form. Sometimes they are borne almost stemless in a cluster around the main stem. Little potatoes constitute evidence of underground injuries, and usually occur late in the season.

The fungus may cause lesions or spots ½ to 1½ inches long on the stem near the surface of the ground. These spots destroy the bark, and may cause the premature death of the stems. Stems which are severely injured but do not die, often produce aerial tubers and a few small underground tubers.

Tops of diseased plants usually have yellow to purple, crowded, upward rolled leaves with prominent veins. The stunted, discolored, rosetted plants resulting from severe injury by Rhizoctonia are easily recognized in the field.

Control.—Treat seed potatoes with mercuric chloride or hot formaldehyde as recommended (p. 13). Adopt a 5-year crop rotation and modern cultural methods. Although the Rhizoctonia fungus occurs in many soils so that perfect control is rare, seed treatment and crop rotation usually enable the potato grower to produce commercially profitable crops.

COMMON SCAB

Scab is common on potatoes and is recognized by most growers. The scab organism is widely distributed and now occurs in the soils of most fields. It is most prevalent and destructive in alkaline soils.

Cause.—Common scab is caused by a fungus called *Actinomyces scabies* (Thax.) Güssow. It resembles bacteria.

Losses caused by the disease.—Scab causes an annual loss of several million dollars in the United States.

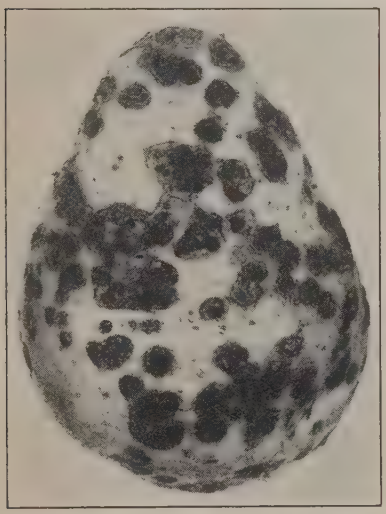

Fig. 5. Common scab on a potato tuber.

(1) The principal loss is in the lowering of the market quality of potatoes by the scab spots. Clean, smooth potatoes command a higher price and readier sale than scabby ones, especially if potatoes are plentiful. There is more waste to scabby potatoes in culinary operations. It has been estimated that ordinary paring losses approximate one-fifth in clean and one-third in scabby potatoes. Very scabby tubers are not desirable for seed, and the scab lesions increase the liability to decay in storage.

(2) Experiments have shown that in severe cases scab reduces the yield from 15 to 20 per cent. Considering 150 to 200 sacks per acre a fair yield of potatoes, this means a loss of 30 to 40 sacks.

Symptoms of Potato Scab.—The scab first appears as small reddish or brownish surface spots, often when the potatoes are very young. They enlarge and darken in color, resulting in a rough pitting of the tubers (Fig. 5). If the attack is early, the scab spots are deep; if the attack is late, they are shallow. Mites often deepen the scab spots. Scab attacks the tubers at any stage from the time they set until they cease growing. It does not attack mature potatoes in the ground or in storage.

Common scab should not be confused with powdery scab, caused by *Spongospora subterranea* (Wallr.) T. Johnson, which is rare in Montana. Powdery scab forms small blisters, or pustules which break through the skin. The skin curls back

around the spot, exposing the brownish or dark-green spore powder. Eel worms, wireworms, etc., often cause a pitting resembling scab, but close observation shows the difference.

Control of Scab.—1. *On fairly clean land.* Use one of the seed treatments recommended (p. 12). This treatment will kill the organisms on the tuber, and will prevent soil infestation from this source.

2. *On infested land.* Seed treatment alone will not insure a clean crop, but it will reduce the damage. Slightly scabby potatoes are not objectionable for seed if they are treated, but very scabby potatoes should not be used. The organism causing scab will live in the soil for many years, so at least a 5-year rotation should be practiced. The causal organism grows best in alkaline soils, so its growth is encouraged by the use of lime, wood ashes, and alkaline commercial fertilizers. Strongly acid soils are practically free from scab. Hence, plowing under a green manure crop will reduce the injury. Applying inoculated sulphur to the soil, which results in the formation of sulphuric acid, is sometimes beneficial.

3. *Resistant varieties.*—Varieties immune to scab have not been developed. The most resistant are the Russet types, variously known as Russet, Russet Burbank, Netted Gem, Idaho Russet, and Carman No. 3.

BLACKLEG

Blackleg is the only bacterial disease of potato that is prevalent in Montana, although others, such as bacterial wilt, occur in other potato sections of the United States.

Cause.—Blackleg is caused by a bacterial organism, *Erwinia atroseptica* (van Hall) Com. S. A. B. (*Bacillus atrosepticus* van Hall.)

Symptoms.—The first symptom of the disease noticeable above ground is a wilting or yellowing of the lower leaves. Later, the upper leaves become yellow or reddish yellow and prominently upward rolled (Fig. 6). Black, somewhat sunken streaks occur on the lower parts of the stem near the surface of the ground. In extreme cases the black streaks extend to the upper parts of the stems, which often fall over. Cutting open the stems near the base reveals black pith. The tubers

Fig. 6. Potato stem dying from blackleg. The main stems are blackened, and the leaves are light green.

often develop a soft rot which usually starts at the stem end. Such tubers may rot entirely, or the disease may be checked at any stage. Infected tubers may perpetuate the disease if planted.

The disease is most destructive during warm, moist summers and autumns. For this reason, it is often not detected until the plants are half grown, or later in the season.

Control.—Because the diseased tuber is probably the main carrier of the disease over winter in Montana, no tubers having dark spots in the flesh should be planted. When a seed stock contains a small percentage of tubers showing the foregoing symptoms, disinfect with cold formaldehyde (p. 13), but treat after the tubers are cut, and for 1 to 5 minutes only.

This treatment will not penetrate and kill the bacteria in the spots but the cutting knives passing through these diseased spots inoculate the cut surfaces of healthy tubers, and the organisms thus transmitted will be killed by this treatment.

A good sanitary practice is to rogue out all hills showing blackleg wherever they are detected. The diseased plants and their tubers should be removed and destroyed. Whenever a field shows a severe infestation of blackleg the crop should be sold, and high grade seed obtained from a new source for the next crop.

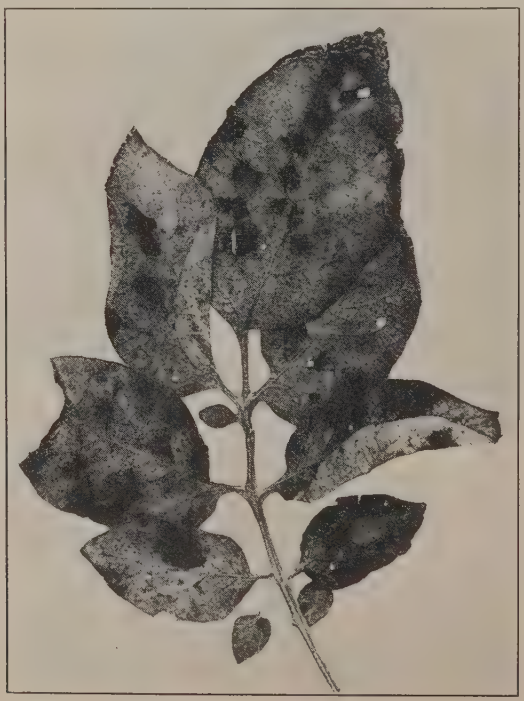

Fig. 7. Early blight caused by Alternaria.

EARLY BLIGHT

Early blight of potatoes has not yet become very serious in Montana, although it did some damage in 1927 and 1928 around Billings, Chinook, and Hardin.

Cause.—Early blight is caused by a fungus called *Alternaria solani* (E. & M.) J. & G.

Symptoms.—The leaves are usually attacked. Large spots with concentric rings or bull's-eye markings are formed on the leaves (Fig. 7). The vine is often killed by the disease if the infection is general and the spots are numerous.

Small, more or less circular spots are sometimes formed on the tubers. These are slightly sunken, and the margins of the diseased areas are somewhat raised. These spots are not very serious in themselves, but often serve as entrance points for rot-producing organisms. No tubers infected with early blight have been observed in Montana.

Control.—The fungus lives over winter in the old plant refuse left in the field, from which it spreads in the spring. Such refuse should be destroyed.

Early blight on the leaves can be controlled by the use of Bordeaux mixture (p. 16). Begin spraying when the disease first appears, and continue at intervals of 10 days.

FIELD WILT

Cause.—Field wilt or Fusarium wilt is caused by a parasitic fungus called *Fusarium oxysporum* Schlecht.

Losses caused by the disease.—Fusarium wilt causes a decrease of more than 3 per cent in the yield of Montana potatoes each year. Wilt is the principal factor limiting the production of potatoes in the famous delta district of the San Joaquin Valley in California. Fusarium wilt causes serious damage in practically all the old potato-growing sections, and is a national problem. It now causes an annual loss of several million dollars in the United States.

Symptoms.—The distinctive characteristics of the disease are wilting, yellowing and premature death of the leaves, with brown streaks usually visible in the bases of the affected stems. Fusarium occurs in the bases of green stems, in the underground runners or stolons, and often in the tubers (Fig. 8).

The time of appearance of the disease varies according to the severity of infection, the age of the plants, and the variety. Generally the disease is not noticeable until the plants are about a foot high, when the lower leaves first droop and die. Later, the other leaves wilt and the entire plant dies prematurely. In mild infections the plants die only a week or two earlier than normal plants. Affected plants usually turn yellow, especially in the advanced stages of the disease.

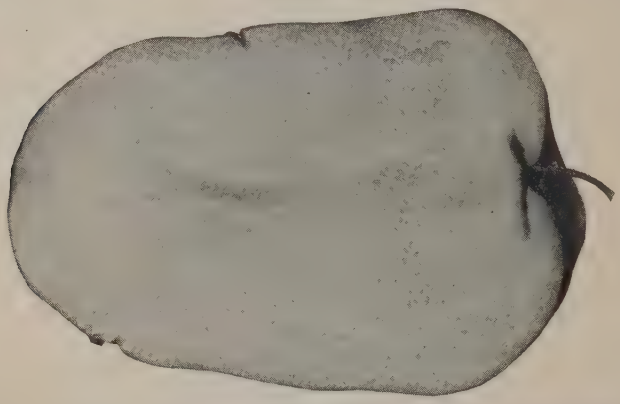

Fig. 8. Field wilt caused by Fusarium; stem end discoloration near surface of tuber a good indicator, when vines have typical symptoms.

The lower portion of the potato stem shows a brown discoloration which extends throughout the root system. As a result of the partial killing of many of the roots, the plants are easily pulled. The roots appear to be dead and brittle.

In the tubers the disease *usually* causes a distinct browning of the vascular ring (Fig. 9). This is very conspicuous in well-defined cases when the tuber is cut across the stem end. This brown ring, however, may be due to environment or to other diseases. It is quite different from the storage dry rot (p. 27).

Control.—There is no definite method of control, but healthy seed potatoes and crop rotation aid considerably. The development of resistant varieties will aid materially in reducing the loss caused by this disease. The most effective method of selecting seed stock free from wilt is by the use of the seed plot (p. 46). Wilted plants and their tubers should be removed from

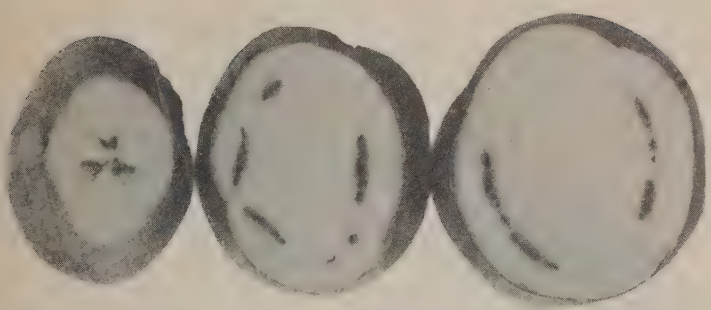

Fig. 9. Field wilt caused by Fusarium; tubers showing brown discoloration of vascular (water-conducting) rings.

the field. An easily recognized symptom of wilt is the browning of the vascular ring, readily seen when the stem ends of the tubers are cut off. Growers should reject for planting purposes all lots of potatoes in which many tubers show such a ring discoloration.

Seed treatment will not control field wilt.

STORAGE DRY ROT

Cause.—Storage dry rot is caused by several species of fungi called *Fusarium,* which are different from the Fusarium causing field wilt. The diseases are different although the causal fungi are closely related.

Losses.—Storage rot occurs wherever potatoes are stored. Generally the loss is about 4 per cent, but in severe cases it may exceed 50 per cent.

Symptoms.—The fungus usually attacks the tuber through breaks in the skin that are caused by rough handling of potatoes during harvesting or storing. The diseased portion of the tuber has a wrinkled, sunken appearance, and later may show cavities and tufts of the mycelium of the fungus (Figs. 10, 11). The diseased tissues vary from nearly black to light brown and may be gray or nearly white, because of the mycelium and spores of the Fusarium fungus.

If the disease has progressed only slightly, a small sunken spot may be the only indication on the surface. Under favorable conditions the rotting continues until the entire contents of the tuber become a dry, powdery mass of decomposed cells,

starch grains, fungous mycelium and spores, leaving merely a cork layer (peel) on the outside.

Potatoes affected by this decay alone are never slimy and do not have a bad odor. If secondary rots occur, such as bacterial rots, there may be disagreeable odors and a wet rot of tubers.

Fig. 10. Storage dry rot of a tuber. Sunken, brown region with white mold (Fusarium).

In the common type of rot occurring in Montana, the fungus attacks the center of the tuber faster than the outside, so that a very small spot on the outside may be underlaid by a rotted region involving as much as three-fourths of the tuber.

This disease does not attack growing plants in the field.

The causal fungus appears to live continuously in many soils. During the growing season, the tubers become contaminated (inoculated) on the surface but not internally. When cut or broken tubers are stored, the fungus gains entrance through the wounds and destroys them, especially if the storage room is too warm and poorly ventilated.

Control.—The fungi causing dry rot are wound parasites, so careful handling during harvesting and storing is recommended. Grade carefully to eliminate all undesirable tubers before storing.

Losses will be slight when tubers are stored in a reasonably dry, well ventilated house which is maintained at temperatures of 35° to 40° F.

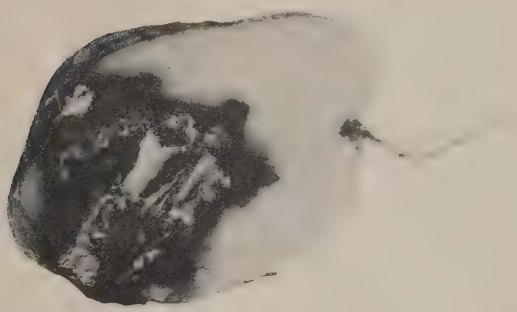

Fig. 11. Internal view of a tuber with dry rot, and the white mold (Fusarium) that causes it.

It is a good plan to clean and disinfect storage houses with copper sulphate or formaldehyde (p. 17) before putting new crops into them.

PHYSIOLOGICAL DISEASES AND OTHER INJURIES

NET NECROSIS

This is a condition of the tuber in which there is a network of brown or black streaks in the flesh. It may be general throughout the tuber, or localized in the outer region, but shows no surface symptoms.

This condition may be a symptom of frost injury, Fusarium wilt, leaf roll, or unfavorable environmental conditions during the growing season. Excessive heat in storage also causes discolorations in the tubers.

The presence of net necrosis makes the stock undesirable for culinary purposes, and reduces its marketable value. Affected tubers should not be used for seed.

SPINDLING SPROUT

The name is descriptive because it designates a condition in which long, slender, spindling sprouts are produced instead of normal, thick, vigorous ones. Leaf roll and witches' broom are common causes of spindling sprout. Other factors which seem to induce it are adverse growing conditions just before harvest time, excessive sprouting, rotting of seed pieces, and storage or growth at too high temperatures.

Spindling sprout indicates a weakened vitality of the tuber. Such tubers should be rejected for seed stock because they produce weak plants.

TIP BURN

This trouble usually prevails whenever hot dry weather continues for a considerable period during July and August. It affects the plant by reducing the leaf area which feeds it.

The leaves turn brown and dry at the tips and margins. The affected areas become hard and brittle with a tendency to turn upward and inward. In severe cases, entire leaves may be affected. The oldest leaves and those on plants affected by some degeneration diseases are the most susceptible. When excessive heat causes the trouble, leaf tissues between the veins are killed. When leaf hoppers (small jumping insects) cause the trouble the browning more definitely follows the veins.

Bliss Triumph, Early Ohio, and Cobbler potatoes are susceptible to tip burn, while the Rural types are more resistant.

Control.—Tip burn can be controlled by spraying with Bordeaux mixture (p. 16). Begin spraying when tip burn first appears, and repeat the applications at intervals of ten days throughout the growing season. Bordeaux acts as a repellant and poison to the leaf hoppers, and in some indirect manner reduces the injury caused by excessive heat.

FROST INJURY

Discoloration of the flesh of tubers often results when potatoes are exposed to low temperatures, commonly referred to as a heavy frost or a light freeze. The average freezing point of potatoes is about 29° F., but this may vary a few degrees, depending upon the variety, previous storage conditions, type of container, duration of exposure, and the like. Under ordinary conditions 29° F. should be considered the danger point in exposing potatoes to low temperature.

Tuber discolorations due to low temperature may appear as: (1) a faint ring necrosis, (2) a ring necrosis in combination with net necrosis of the flesh, (3) blotches near the surface, (4) under moderate freezing all discoloration disappears and soft potatoes result with a sour odor and flabby texture, and (5) under severe freezing the "leaker" stage results. In this stage the sap escapes from the potato as soon as it thaws out, but no discoloration of the flesh results.

Control.—Potatoes should not be exposed to temperatures of 29° F., or colder. Ridging in the field helps to prevent such injury there.

HOLLOW HEART

This name is very descriptive as it applies to potato tubers with irregularly shaped white to brown cavities in their centers. This abnormal condition is confined mainly to large or over-sized tubers. It is thought to be the result of too rapid development during the growing season. Decay is not associated with the cavity except when rotting fungi or bacteria enter from the outside.

The losses consist mainly in a reduced market value, and waste in the culinary processes.

The only known method of control is to follow cultural practices which will tend to reduce the number of over-sized tubers.

BLACK HEART

Black heart is caused by overheating or poor ventilation of tubers. The symptoms are large black regions or cavities lined with black tissue, in the center of the tuber. These cavities are sometimes white until they are exposed to the air.

This condition is usually found in potatoes which have been overheated in transit, or stored under unfavorable conditions. Black heart has been produced artificially by exposing tubers to temperatures of 100° to 113° F., for 12 to 18 hours, or keeping them under poorly ventilated conditions.

The remedy is proper storage and avoidance of overheating in transit.

TUBER FORMATION IN DARK STORAGE

Potatoes stored in a dark place at 40° to 70° F. for 8 months or longer, often produce new tubers (0.1 to 2 inches in diameter) on the ends of sprouts from the eyes. The sprouts may be a few inches long, or inconspicuously short. The sprouts and tubers are small and numerous on tubers stored in darkness for a year at 30° to 40° F. Old tubers naturally produce stems and new tubers, even under these abnormal conditions. Planted tubers without aerial stems sometimes produce such new tubers. Occasionally, new tubers are produced inside the old tubers.

SUNBURN

Whenever tubers are exposed to sunlight or even to strong diffused light for many hours, they develop a green or red color, due to the formation of chlorophyll, which is the compound that gives the green color to leaves. Greened potatoes are objectionable for culinary purposes because they are bitter, and may be poisonous to some people. Greening does not injure the tuber for seed.

To prevent this condition keep potatoes well hilled in the field and store the tubers in the dark. The color will usually disappear from green potatoes after they are stored in darkness for several weeks, unless the greening is very prominent.

ENLARGED LENTICELS

Inquiries are often received regarding the white specks on tubers that grew in wet soil, or that have been stored where the humidity was very high. These white specks are lenticels or breathing pores, which are usually inconspicuous, but become greatly enlarged when the tubers are kept under very moist conditions. On dry tubers the lenticels appear as small brown specks. Enlarged lenticels do not injure the tubers.

QUACK GRASS INJURY

When quack and some other grasses are allowed to grow in a potato field, their root stocks will sometimes pierce the potato tubers. This is a purely mechanical injury, but is often quite a curiosity. The wounds affect the market value of the tubers.

VIRUS DISEASES OF POTATOES

INTRODUCTION

Potato growers have recognized destructive virus or "running out" diseases which greatly reduced the yield of their potatoes since 1775. Extensive research work during the last 20 years has proved that these diseases are caused by viruses (p. 10). A disease resembling mosaic was described in Europe in 1847.

Virus diseases are very infectious, and are spread by transferring the sap of diseased plants. Very impressive circum-

stantial evidence from many investigations has led to the general opinion that some living organisms in the sap of diseased plants cause the virus diseases, although the causal parasites have not yet been recognized. Successful control measures have been based on this assumption. Potatoes are only one of the many crops damaged by virus diseases.

Tubers from plants with a virus disease carry the causal virus. Seed stocks usually degenerate rapidly when part of the tubers are diseased. Hence, the main advantage of certified seed potatoes is their comparative freedom from virus diseases.

Aphids (plant lice, green bugs) are the most important of the known agents that spread potato virus from diseased to healthy plants in the field. In Montana, aphids are often abundant in potato fields during the last month of the growing season. Sometimes they are too scarce to do serious damage.

Aphids are generally abundant during most of the growing season in the humid parts of the United States. In the South they spread the virus diseases so rapidly that many growers find it profitable to buy certified potatoes from the North.

Control measures recommended for virus diseases are discussed in detail under Methods to Control Diseases (p. 10), and Control of Virus Diseases of Potato (p. 46).

Virus diseases may be grouped for convenience as follows:

1. Mosaic group, which includes rugose, crinkle, mild and super-mild mosaic, and mottled curly dwarf.
2. Spindle tuber group, which includes spindle tuber, giant hill, and unmottled curly dwarf.
3. Leaf roll.
4. Witches' broom.
5. Miscellaneous group, which includes spindling sprout, yellow dwarf, and psyllid yellows.

RUGOSE MOSAIC

Symptoms in vines from diseased tubers.—The most dependable symptom of mosaic is the mottling of the green leaves with yellow or light green spots. (This mottling is easily seen during the cool weather of spring and fall, but often disappears after the temperature has been above 70° F. for a week.) The leaves are also badly wrinkled and have ruffled edges (Pl. I, A, B,

Plate I. Bliss Triumph Potatoes

A. Normal leaflets.

B. Leaflets mottled (light colored spots), ruffled, wrinkled, and dwarfed by rugose mosaic.

C, D, E. Leaflets showing current season infections with rugose mosaic. Lower sides of veins and midribs turned black or brown, and brown dead spots appeared.

F. Normal leaflets.

and Fig. 12). The diseased plants are usually light colored and only about half as large as normal plants. They yield only 10 to 50 per cent as much as healthy plants. Potatoes having this disease in extreme form produce no tubers of commercial value. Vines with rugose mosaic may also be recognized by their small, wrinkled, light-colored leaves.

Fig. 12. Rugose mosaic in Bliss Triumph potato (right) in comparison with normal plant (left). Diseased leaflets are dwarfed, mottled, ruffled, wrinkled, and curled. The lower leaves die and often drop. Stems are rigid and narrow.

Symptoms in vines infected in the field.—When aphids feed on potato plants affected with rugose mosaic and then feed on healthy plants, they often transfer the virus of rugose mosaic to the healthy plants, which show symptoms of the disease within a week or two. Small brown spots 1/16 to ¼ inch in diameter often appear near the points of infection. The lower sides of the veins in some leaflets turn brown or black (Pl. I, C-F and Fig. 13). Brown to black streaks appear on the petioles

of the leaves and on the stems. Parts of leaflets, whole groups of compound leaves, and often whole stems die within a few weeks after infection (Fig. 13). Sometimes new leaves growing from the tops of the stems show mottling and wrinkling.

Fig. 13. Current-season symptoms of rugose mosaic in a Bliss Triumph potato resulting from leaf-mutilation inoculation with virus from an Irish Cobbler potato.

These current-season or primary symptoms are readily distinguished from injuries caused by frost, dry weather, cultivation and the like, with which they are often confused.

The tubers become diseased with rugose mosaic unless they are dug within a few days after the tops become infected.

Importance.—This is one of the most destructive of the virus diseases, because it is common, spreads very rapidly in the field, and reduces the yield greatly. The disease called russet dwarf appears to be similar to rugose mosaic but the mottling is masked.

CRINKLE MOSAIC

The symptoms of crinkle mosaic are light color, ruffling and mottling of the leaves (see title page), dwarfing of the stems, and considerable reduction in the yield of marketable tubers. The mottled spots are large. Crinkle mosaic reduced the yield 41.7 per cent in Bliss Triumph potatoes in plots at the Experiment Station at Bozeman (Table 1).

Crinkle mosaic is less contagious and destructive than rugose mosaic. However, it is very common and does great damage.

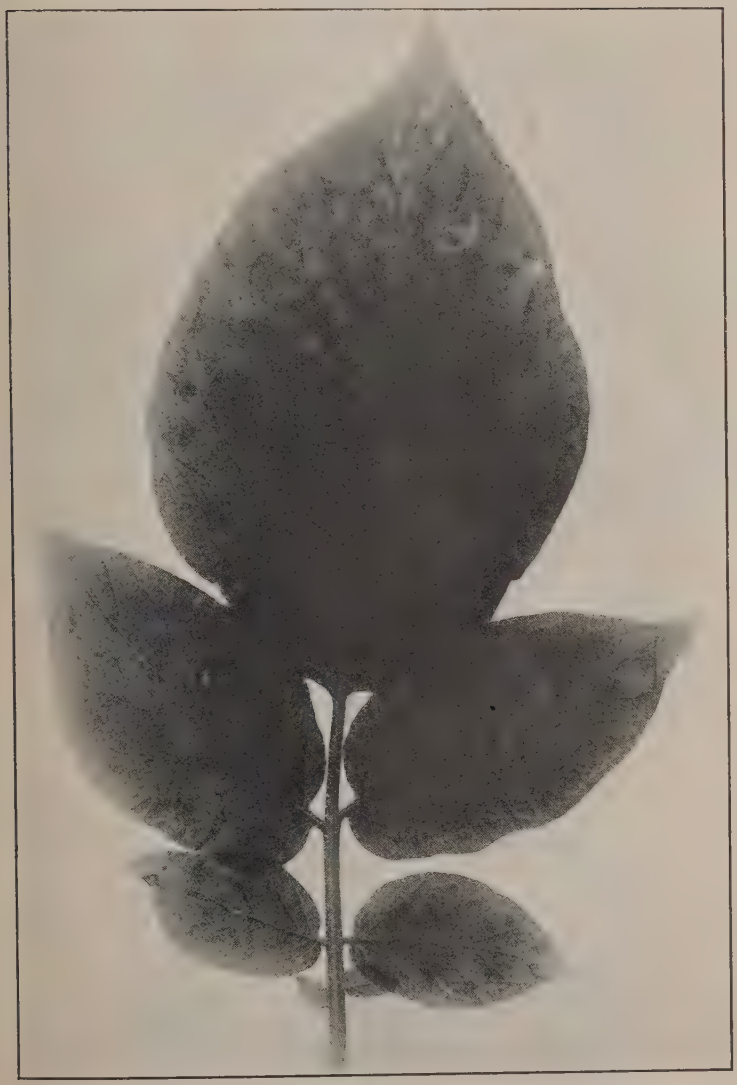

Plate II

Netted Gem potato leaflets showing mottling as the only symptom of super-mild mosaic.

SUPER-MILD MOSAIC

The only symptom of this disease is a faint mottling, which is often masked unless conditions are favorable (Pl. II). However, in yield plots with Netted Gem potatoes, it caused a 19.1 per cent reduction in yield (Table 2). Affected plants should be removed.

MILD MOSAIC

Potatoes with mild mosaic are often dwarfed and have leaves that are mottled and often ruffled. Otherwise the plants appear normal. In yield plots with Idaho Rural potatoes, it reduced the yield 23.1 per cent (Table 2). Affected plants should be removed.

MOTTLED CURLY DWARF

Mottled curly dwarf appears to be a combination of spindle tuber and mosaic diseases. It is recognized by the narrow, upright, dwarfed vines with rolled, curled, dwarfed, wrinkled, mottled, often light-colored leaves. It reduces yields 50 per cent or more.

Fig. 14. Potato plant with spindle tuber, showing narrow upright type of growth.

SPINDLE TUBER

Potato vines showing distinct symptoms of spindle tuber are upright, dwarfed in height, and much narrower than normal vines. The stems are often more branched than usual, with the upper angles of the branches and stems abnormally acute (Fig. 14). In many cases the leaves are smaller and more pointed than normal. Affected tubers are dwarfed and are

Fig. 15. Netted Gem potatoes showing symptoms of spindle tuber. Note dwarfed, spindle-shaped and cracked tubers. N.—normal tuber. Two-thirds natural size.

usually narrower and more spindle-shaped than normal ones (Fig. 15). The eyes are usually abnormally numerous. The tubers are often cracked. Many Bliss Triumph potatoes affected with spindle tuber are oblong instead of spherical, and may be light colored and cracked (Figs. 16, 17). Plants mildly affected with spindle tuber are very difficult to recognize and are sometimes confused with giant hill. Aphids and some other insects spread spindle tuber from diseased to healthy potatoes in fields.

Spindle tuber reduced the yield of potatoes from 35.3 to 75.9 per cent, depending mainly upon the severity of the symptoms (Table 2).

Fig. 16. Normal Bliss Triumph potato tubers.

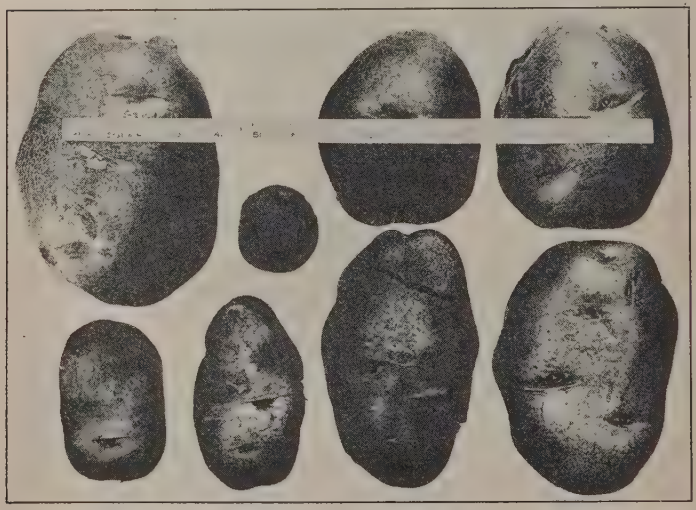

Fig. 17. Bliss Triumph potato showing dwarfing, elongation, and too many eyes, as symptoms of spindle tuber.

Fig. 18. Bliss Triumph potatoes. Those marked "GH" are distorted and cracked, and show symptoms of giant hill. "N" means normal tubers.

GIANT HILL

Giant-hill potatoes have abnormally large, coarse vines. They are most easily recognized near the end of the growing season because they bloom more abundantly and remain alive longer than normal plants, and they are more resistant to frost and early blight. Giant-hill vines usually produce a fairly large yield of large, rough, irregular, off-type tubers that are some-

times cracked (Fig. 18). This abnormality is carried and spread by the tubers, but is not known to be transmitted to healthy potatoes. Although it has not been proved to be a disease, producers of seed potatoes should remove giant-hill plants because they are badly off-type.

UNMOTTLED CURLY DWARF

Potato leaves with this disease are greatly dwarfed and wrinkled, but are not mottled. The tubers are often irregular and cracked, and are dwarfed. It is contagious and reduces yields about 85 per cent, so affected potatoes should be rogued.

Fig. 19. Burbank potato dwarfed by leaf roll, showing the prominently rolled leaves.

LEAF ROLL

The leaf-roll disease causes the potato leaflets, especially the lower ones, to roll upward and become brittle, light colored, and dwarfed (Fig. 19). The internodes (parts of stems between the joints) are abnormally short. The vines are dwarfed, with short stems, and produce a rustle like paper when shaken gently. They bear small numbers of tubers on very short

stolons. Spindling sprouts may grow from the eyes of such tubers when planted or stored. Rolling and brittleness of a few bottom leaves on large vines is often due to contact with hot soil in fields, but this symptom is too mild to be confused with leaf roll. Aphids spread leaf roll rapidly in the field. In plants affected late in the summer, the symptoms are rolling, brittleness, and light color in the top leaves. The older leaves on such plants appear to be normal. If the plants are infected just before they mature, the tubers may become diseased without the symptoms appearing in the tops. In such cases, the disease is not detected until the resulting vines show the leaf roll symptoms.

This disease is not very common in Montana. It reduces the yield from 50 to 75 per cent in diseased plants.

WITCHES' BROOM

Symptoms in vines infected in the field.—The current-season symptoms of witches' broom are very important. The tops

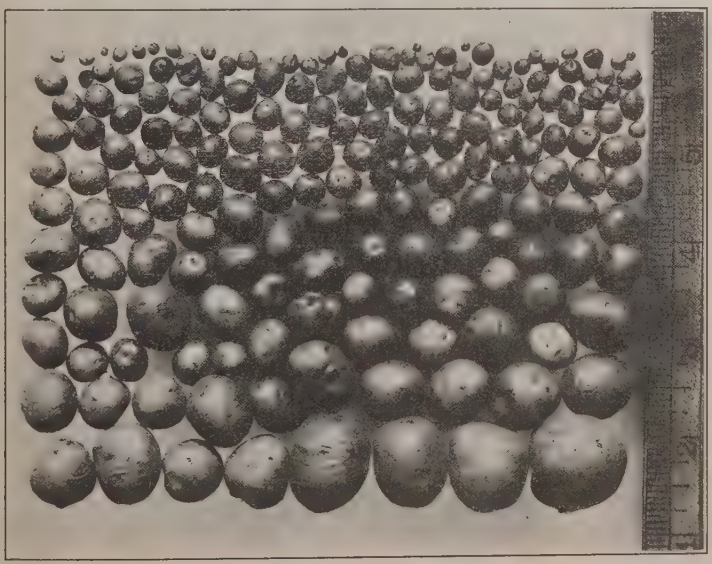

Fig. 20. One hill of potatoes dug on September 25, 1915. The 184 tubers cover an area of only 25 square inches. The parent plant had witches' broom. (Printed originally in Jour. Agr. Res. 36:835.)

of fairly large vines turn yellow, and yellow margins appear on many new leaflets. Later, aerial tubers often appear on the stems. The underground tubers may sprout prematurely, sending up many spindling little stems around the old vines. When such plants grow for a month or two after the symptoms have appeared, they usually produce 40 to 200 very small tubers and a few large ones (Fig. 20). Witches' broom probably is carried to the succeeding crops mainly through these large, infected

Fig. 21. Witches' broom in a Bliss Triumph potato, showing numerous spindling stems with small leaves. One-third natural size. (Printed originally in Jour. Agr. Res. 36:841.)

tubers, so plants showing these symptoms should be removed, with their tubers. This disease obviously spreads to healthy potatoes in the field, although the exact means has not yet been determined. It is easily transmitted by grafting together diseased and healthy stems or tubers.

Symptoms in plants from diseased tubers.—Tubers having witches' broom produce many spindling little sprouts. Resulting plants are usually much dwarfed with very small leaflets (Fig. 21). The leaflets often have yellow margins. Small tubers commonly occur on the stems. Such plants bear from 10 to 100 tubers apiece which are only 1/16 to 2 inches in diameter.

Importance.—Witches' broom made a field of 30 acres of potatoes in Washington nearly worthless. In many potato fields

in Montana, 5 to 20 per cent of the plants have been affected with this disease since 1915. Witches' broom reduces the yield of marketable potatoes from 10 to 50 per cent on vines with current-season symptoms, and vines from diseased tubers bear few or no marketable tubers.

CALICO

The large, irregular, angular, yellow to white calico blotches in the potato leaves make this abnormality easy to recognize. It is usually carried in the tubers from affected plants, but is not definitely known to be contagious. Experiments to transmit it to healthy plants have failed. Calico vines produce poorly, so they should be rogued out of fields of seed potatoes.

SPINDLING SPROUT

Spindling sprout is not a separate disease. It is a symptom of witches' broom and of leaf roll. When diseased tubers are stored or planted, one or more slender sprouts grow from the eyes. Some physiological conditions, such as too warm storage, excessive sprouting and the like, also cause tubers to produce spindling sprouts. Such tubers should not be planted because they produce weak, often diseased vines.

PSYLLID YELLOWS

A very destructive disease occurred in Utah in 1927 and 1928, which also did serious damage in Colorado and was seen in neighboring states. Although apparently unrelated to leaf roll and witches' broom, it has some of the symptoms of both diseases. The lower leaves roll upward, turn yellow, red, pink, or purple, and die prematurely. The joints of the stems often swell, and bear thick shoots, aerial tubers, and rosettes of small leaves. This very serious disease is spread from diseased to healthy plants by the feeding of a little insect called a psyllid or jumping plant louse, that is related to the ordinary plant louse or aphid.

Some Irish Cobbler and Burbank potatoes growing in Bozeman in 1927 showed early symptoms of psyllid yellows, so it may become serious in Montana. If it appears, specimens should be sent to the Botany Department of the Montana Agricultural Experiment Station for identification.

YELLOW DWARF

This disease occurs in some eastern states. The vines are greatly dwarfed, turn greenish-yellow, and usually die prematurely from the top downward. The top leaves are often purpled and rolled upward. Cutting reveals brown specks in the stems, especially in the joints. Tubers on affected plants contain brown spots, and are often cracked, even though they are small.

Yellow dwarf is very injurious.

This disease has not been reported in Montana. Plants showing symptoms as described above should be sent to the Botany Department of the Agricultural Experiment Station for identification.

CONTROL OF VIRUS DISEASES OF POTATOES

The best method of controlling virus diseases is growing seed each year in a carefully rogued, isolated seed plot. This method has been recommended by the Montana Experiment Station for twelve years. Because of its importance, this method will be discussed in detail.

POTATO SEED PLOT

Object.—The object of the seed plot is to improve the seed.

Size.—In order to furnish sufficient seed, it should be about one-tenth as large as the acreage to be planted in the field.

Location.—The seed plot should be located on ground which has not recently produced potatoes and is well adapted to growing them. It should be isolated, being at least 200 yards from field crops of potatoes, as this affords considerable protection from aphids flying to it from other fields. Aphids are the principal agents in carrying virus diseases from plant to plant.

Seed.—Use high quality seed stock. Treat all seed with either hot formaldehyde or corrosive sublimate solutions (p. 13). Discard all tubers that show internal molds or rots, because moldy tubers produce weak plants. Careful inspection during cutting of the seed may reduce trouble from blackleg (p. 22).

Planting.—Recent work has shown that there is a marked difference in the growth of potatoes from different-sized seed

pieces. Therefore, grade all seed stock, cutting it in such a manner that the seed pieces will be about equal in size in order to promote uniform growth. Plant by the tuber-unit method in which all seed pieces from a single tuber are planted adjacently in the row. A gap or space between tuber units is advisable to mark the limits of each tuber. Tuber-unit planting facilitates roguing, as degeneration diseases are more easily detected in units of plants than in an individual plant in a mass-planted field. Some growers in Montana have found that it is profitable to plant whole fields in tuber units.

Care.—The seed plot should receive the best cultural care.

Roguing.—Roguing consists of pulling out all diseased, weak, abnormal, or otherwise undesirable plants with their seed pieces and tubers. It assumes the ability of the workman to detect varietal mixtures and diseases such as virus diseases, blackleg, Fusarium wilt, Rhizoctonia, and the like, in their various forms. The symptoms of most virus diseases from infected tubers are apparent within two months after planting. Roguing early in the season is therefore beneficial as it eliminates these plants which otherwise would be the sources of infection. A seed plot should be rogued every ten days during the early part of the season. Later, the intervals may be lengthened according to the judgment of the grower.

The symptoms of any one disease are most readily visible under certain conditions. For instance, mottling of leaves is more readily seen when the leaves are shaded, when they are not wet, and when they have not been recently sprayed with lead arsenate, Bordeaux mixture, etc. Plants affected with giant hill bloom more profusely and are more resistant to light frost than are normal plants. Potatoes with degeneration disease often appear to be more susceptible to attacks by the potato bug.

In roguing, the plants with their seed pieces or tubers should be removed from the seed plot and burned or deeply buried. Placing the rogued plants in burlap sacks, being careful not to shake the aphids from them, is a convenient and practical way to collect the plants before destroying them.

Spraying.—It may be necessary to spray the seed plot with Bordeaux mixture (p. 16) to protect the plants from early

blight and tip burn. Potato bugs (Colorado potato beetles) are controlled by applying lead arsenate, zinc arsenite, or Paris green. If aphids become numerous in a seed plot they can be controlled by spraying the plants with a solution of nicotine sulphate. This spray is practical in a valuable seed plot in which aphids threaten to spread virus disease seriously. (Detailed information regarding the control of insects affecting potatoes may be secured from the Entomology Department, Montana Experiment Station, Bozeman.)

Improvement of seed stock.—To secure the best seed for the seed plot, stake the hills which show vigorous growth and the desired type of vine. Dig these by hand, and save for seed only those which have a high yield of tubers of uniform size and shape.

Digging.—The seed plot should be harvested under favorable climatic conditions, using special care in handling the crop to avoid injuring the tubers.

In an emergency when a disease like rugose mosaic is beginning to spread rapidly in a field, a seed stock may be saved

Fig. 22. Plot of diseased potatoes at the Montana Experiment Station, showing the cloth cages used to protect special hills from insects that would otherwise carry diseases to them.

by immediately harvesting the crop, even though the tubers are very immature. It is a valuable method only in so far as the tubers are dug before they become infected through the tops (p. 35), and should be practiced only in special cases.

Storage.—The seed stock should be stored in a well-ventilated storage room at a constant temperature of about 40° F. Danger of mixing seed stock with the field crop should be avoided.

Results.—The results of the past few years have demonstrated that seed potatoes of high quality can be raised profitably in Montana by the seed-plot method.

When this seed is used for planting fields of seed potatoes, it makes roguing cheap and easy because relatively few diseased plants appear.

EFFECTIVENESS OF ROGUING A SEED PLOT TO REDUCE VIRUS DISEASES

To test the effectiveness of roguing, uniform lots of potatoes containing more than 23 per cent of mosaic and 21 per cent of leaf roll, respectively, were planted in 1927 in four plots of 800 hills each.* Two plots were planted with Burbank potatoes with mosaic, and two with Netted Gem potatoes with leaf roll. The hills were 20 inches apart in the rows. All were rogued carefully at intervals of 10 days after the plants appeared.

Representative samples were selected from these plots and used in planting similar plots in 1928. These plots were carefully rogued as stated above. The following percentages of diseased plants were removed from the plots, leaving them nearly free from degeneration diseases.

From the two plots of Netted Gem potatoes, 21 per cent of the plants were removed in 1927, and 2.3 per cent in 1928 because they had leaf roll and mosaic.

From the two plots of Burbank potatoes, 23.2 per cent of the plants were removed in 1927 because they had crinkle mosaic, and 0.39 per cent in 1928 because they had mosaic.

Similar plots were planted in 1929, using a seed stock of Bliss Triumph potatoes containing much mosaic, and a seed

*This is a cooperative project involving the Agricultural Experiment Stations in Montana, Oregon, and Utah, and the United States Department of Agriculture.

stock of Netted Gem potatoes containing much spindle tuber. Careful roguing removed 41 per cent of the Bliss Triumph plants, most of which had mosaic, and 32 per cent of the Netted Gem plants, most of which had spindle tuber. However, it would be hardly profitable for a farmer to try to clean up such badly infested seed stocks.

Two plots of each variety were planted in tuber units in 1928 and 1929. Roguing was much easier and certain, and required less time in these plots than in the mass-planted plots, *so tuber-unit planting is recommended highly. It reduces the cost of roguing.*

VIRUS DISEASES REDUCE YIELDS

Experimental plots of potatoes were planted in 1927, 1928, and 1929 to determine the reduction in yields caused by mosaic and spindle tuber.

The potatoes were planted 20 inches apart in the row in alternating groups of four diseased and four healthy hills, so they had the same growing conditions. The rows were 3 feet apart; hence, they were planted at the rate of 8,712 hills per acre. The wide spacing in the rows reduced the effects of the hills on each other. Vines having combinations of diseases and diseased plants in the checks were rogued early each season. The plots were not irrigated, but received a little sub-irrigation water.

The figures given in Tables 1 and 2, indicating reduction in yields, represent the reductions in yields caused by 100 per cent infestations of the diseases in each case.

The yields per acre and the reductions in yields in the plots were calculated from the totals of the hills and yields for each group. The following formula and example show the method of calculation.

$$\frac{\text{Yield (pounds)}}{\text{Number of hills}} \times \frac{8712 \text{ (hills per acre)}}{60 \text{ (pounds per bushel)}} = \text{Bushels per acre}$$

$$\text{Example: } \frac{194}{91} \times \frac{8712}{60} = 309.5 \text{ bushels per acre}$$

TABLE 1.—REDUCTIONS IN YIELDS OF POTATOES CAUSED BY VIRUS DISEASES

Variety	Disease	Year	Number of hills	Yield in pounds	Caculated yield in bus. per acre	Per cent reduction in yield
Bliss Triumph	Normal	*1927	91	194	309.5	
Bliss Triumph	Normal	**1927	88	239.5	395.2	
Bliss Triumph	Normal	1928	177	605	496.3	
Bliss Triumph	Normal	1929	200	506	367.4	
Average					392.1	
Bliss Triumph	Spindle tuber	**1927	114	144.5	184.1	53.4
Bliss Triumph	Spindle tuber	1928	179	310	251.4	49.4
Bliss Triumph	Spindle tuber	1929	58	95	237.8	35.3
Average					224.4	42.8
Bliss Triumph	Crinkle mosaic	*1927	139	195	203.7	34.2
Bliss Triumph	Crinkle mosaic	1928	270	463	249.0	49.8
Bliss Triumph	Crinkle mosaic	1929	99	159	233.2	36.5
Average					228.6	41.7
Irish Cobbler	Normal	1928	87	333.5	556.6	
Irish Cobbler	Spindle tuber	1928	108	229	307.8	44.7

*The units of normal hills were mixed with those diseased with crinkle mosaic.
**The units of normal hills were mixed with those diseased with spindle tuber.

TABLE 2.—REDUCTIONS IN YIELDS OF POTATOES CAUSED BY VIRUS DISEASES

Variety	Disease	Year	Number of hills	Yield in pounds	Caculated yield in bus. per acre	Per cent reduction in yield
Netted Gem	Normal	1927	91	216	344.7	
Netted Gem	Normal	1928	163	658.5	586.6	
Netted Gem	Normal	1929	200	642	466.1	
Average					465.8	
Netted Gem	Spindle tuber	1927	89	51	83.2	75.9
Netted Gem	Spindle tuber	1928	185	307.5	241.3	58.9
Netted Gem	Spindle tuber	1929	88	74	122.1	73.8
Average					148.9	68.0
Netted Gem	Super-mild mosaic	1928	67	227.5	493.0	16.0
Netted Gem	Super-mild mosaic	1929	100	247	358.6	23.1
Average					425.8	*19.1
Idaho Rural	Normal	1928	62	191.5	448.5	
Idaho Rural	Normal	1929	96	209	316.1	
Average					382.3	
Idaho Rural**	Mild mosaic	1928	95	218	333.2	25.7
Idaho Rural	Mild mosaic	1929	100	175.5	254.8	19.4
Average					294.0	23.1

*Netted Gem checks in 1928 and 1929 had an average yield of 526.3 bushels per acre. This variety is also called Russet Burbank.

**Mottling and ruffling of the leaves were constant symptoms.